Thin layer activation analysis in ^{16}O+^{174}Yb system

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In recent years, the thin layer activation (TLA) technique has gained widespread use as a highly sensitive tool for studying surface wear at the micron scale in metallic surfaces of various engineering components. The reliability of industrial equipment, transportation systems, and both nuclear and conventional power plants is significantly affected by processes such as wear, corrosion, and erosion [1–3]. Therefore, the development of effective methods for detecting, measuring, and monitoring these processes is crucial. This is a critical aspect, as preventing hazardous accidents during the operation of industrial installations and minimizing production losses due to machine breakdowns is essential. Charged particle activation for the measurement and monitoring of corrosion and wear is particularly valuable when certain areas of the surface are not easily accessible. Techniques for studying surface phenomena that are highly precise and accurate results in significant savings for industry. Due to their constrained sensitivity range and time-consuming nature, several conventional techniques, such as gravimetric, mechanical, chemical, and optical procedures, are found to have their own limitations in real-world settings [4–7].The TLA technique is a powerful method in which radioactivity is induced in thin layers of metallic foils by bombarding them with light and/or heavy charged particles, such as protons, α-particles, oxygen beams etc. These particles produce radioactive residues in the target material through nuclear reactions. The distribution of these radioactive residues as a function of depth provides a profile of surface wear. The yield of a specific radioisotope can be determined by the measured cross-sections for the nuclear reaction responsible for its formation. The cross-sections for the production of residual nuclei through medium-energy nuclear reactions are significant not only for advancing reactor technology but also for a wide range of basic and applied sciences.

Ytterbium (Yb) acts as a potential neutron absorber in nuclear reactors or as a dopant material to enhance the mechanical properties of stainless steel [8]. It is also used in a type of solid-state laser that use a host material doped with ytterbium ions as their gain medium [9]. In present work, the TLA technique has been investigated for ^{16}O+^{174}Yb using γ-spectroscopy for several isotopes, which are potentially relevant to reactor technology. The cross-section of the several residues populated in the system ^{16}O+^{174}Yb has been measured at energies ≈75-100 MeV. The experiment was carried out at the Inter University Accelerator Center (IUAC), New Delhi. The stacked foil activation technique, followed by γ-spectroscopy, was employed. The radioactive residues populated were identified by their characteristic γ-lines and measured half-lives. The intensities of these γ-lines were used to deduce the cross-sections of the populated radioactive residues. In the present work, the measured cross-sections were used to obtain the yield curves for residues $^{185,186,187}Pt$, $^{185,186}Ir$ and $^{182,183}Os$ at different

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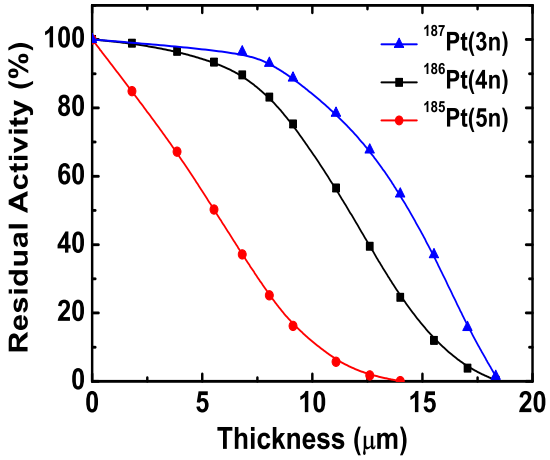

FIG. 1: Calibration curves of isotopes $^{185,186,187}Pt$ populated through xn channels in the interaction of ^{16}O with ^{174}Yb.

depths of target material. Area under the yield curve of a particular isotope across different energies were integrated to obtain the net yield of that radioisotope. Further the yield curves can be used to obtain the calibration curve. If A is the total activity induced and A_{n-1} is the remaining activity after removing thickness δx_1, then the ratio $\mathbf{R}_A$ can be expressed as;

$$\mathbf{R}_A = \frac{A_{n-1}}{A} = \frac{\sum_{i=2}^{n} \sigma_i \delta x_i}{\sum_{i=1}^{n} \sigma_i \delta x_i} \qquad (1)$$

From the given expression, it is evident that the ratio is independent of the number of target atoms, beam current, and irradiation time. Thus, the ratio $\mathbf{R}_A$ can be regarded as the mathematical foundation for determining the amount of material (thickness) lost by surface wear in the thin layer activation technique. The calibration curve is obtained by plotting the percentage of the residual activity (calculated graphically after removing a specific depth of material) against the depth of the material. It has been observed that the residual activity of different reaction products populated by xn, pxn, and αxn channels contributed up to ≈18 μm depth from the surface. As a representative case, the remnant activity induced in the Yb material for nuclides populated via xn channels is shown in Fig. 1. As can be seen in figure, there is a significant drop in residual activity for ^{185}Pt suggesting that most of the wear or surface degradation occurs near the outer layers of the material. This indicates that ^{185}Pt is predominantly affected by surface-level interactions, and the material experiences significant wear in the topmost/front layers. In case of $^{186,187}Pt$, the residual activity gradually decreases with the depth indicating that the wear is distributed more evenly across the layers for these isotopes. The material is likely undergoing consistent wear at intermediate depths, which suggests better resistance to surface wear than ^{185}Pt. Further details regarding measurements and analysis will be presented.

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